Graft complexity-related outcomes of fenestrated endografting for abdominal aortic aneurysms

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Graft Complexity–Related Outcomes of Fenestrated Endografting for Abdominal Aortic Aneurysms

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Abstract

Purpose: To report the outcomes of fenestrated endovascular aneurysm repair (FEVAR) and compare early and midterm results in relation to stent-graft complexity. **Methods:** Between August 2006 and December 2014, 141 consecutive patients (mean age 72±7.6 years, range 50–89; 120 men) were treated electively with FEVAR for short-neck, juxtarenal, or suprarenal aortic aneurysms. Forty-five patients treated with stent-grafts featuring renal-only fenestrations were assigned to group A, while 96 patients receiving additional fenestrations for the superior mesenteric and/or celiac arteries were assigned to group B. Technical success, operative mortality and morbidity, target vessel patency, endoleak, reintervention, and survival were compared between the groups. Survival, target vessel stent patency, and reintervention during follow-up were estimated by Kaplan-Meier analysis; the estimates are presented with the 95% confidence interval (CI). **Results:** Technical success was achieved in 135 (95.7%) patients. Overall 30-day operative mortality was 3.5% (5/141). Perioperative complications occurred in 16 (12.1%) patients. Mean follow-up was 33±23 months. Overall estimated survival was 85.1% (95% CI 79.1% to 91.1%) at 1 year and 75.8% (95% CI 68.2% to 83.5%) at 3 years. Freedom from reintervention was 90.6% (95% CI 85.6% to 95.6%) at 1 year and 79.2% (95% CI 71% to 87.5%) at 3 years. There was no statistically significant difference between the groups in terms of perioperative mortality or morbidity, endoleak, survival, target vessel patency, or reintervention. **Conclusion:** The use of FEVAR for juxta- and suprarenal aneurysms is associated with low 30-day mortality/morbidity and high midterm efficacy. So far, perioperative and midterm results are not affected by the use of more complex fenestrated designs.

Keywords

abdominal aortic aneurysm, celiac artery, fenestrated stent-graft, juxtarenal aneurysm, renal arteries, superior mesenteric artery, suprarenal aneurysm, visceral arteries

Introduction

Following the widespread application of standard endovascular aneurysm repair (EVAR), endovascular techniques have evolved to address more complex aortic pathologies. The use of fenestrated endovascular aneurysm repair (FEVAR) was introduced in 1999.[1] Improvements in technology have enabled treatment of juxtarenal abdominal (JAA), suprarenal abdominal (SAA), and thoracoabdominal (TAAA) aneurysms. The efficacy of FEVAR in the treatment of JAA and SAA has been demonstrated in several reports.[2–4] FEVAR is associated with low operative mortality, comparing favorably to open surgery in terms of morbidity, and seems to constitute a valid treatment option in both low- and high-risk patients.[5]

The concept of fenestrations and scallops in the graft fabric is to extend the sealing zone of the aortic stent-graft to a healthy segment of the aorta at the level of the renal or visceral arteries. The initial assumption was that with a higher number of fenestrations, the complexity and potential pitfalls of the procedure would rise significantly. With time, the expansion of the technique, as well as increasing operator experience, have led to the use of more complex devices with an increasing number of fenestrations incorporated in the stent-graft.[3]

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Table 1. Patient Characteristics and Procedure Data.[a]

Variable	Group A (n=45)	Group B (n=96)	p
Age, y	72.3±7.2	71.8±7.7	0.57
Men	37	83	0.61
Aneurysm diameter, mm	59.4±9.8	58.4±10.2	0.50
Smoking (current or past)	36 (80.0)	80 (83.3)	0.64
Hypertension	41 (91.1)	93 (96.9)	0.21
Diabetes mellitus	7 (15.6)	25 (26.0)	0.19
Hypercholesterolemia	28 (62.2)	63 (65.6)	0.71
CAD	36 (80.0)	63 (65.6)	0.11
COPD	28 (62.2)	45 (46.9)	0.11
GFR, <60 mL/min/1.73 m^2	15 (33.3)	43 (44.8)	0.19
GFR, mL/min/1.73 m^2	62.7±17.2	59.4±19.1	0.27
Previous aortic surgery	7 (15.6)	29 (30.2)	0.07
ASA ≥III	32 (71.1)	64 (66.7)	0.70
Procedure time, min	256±119	273±99	0.57
Fluoroscopy time, min	40 (10–150)	50 (20–160)	0.01
Contrast agent, mL	245 (105–361)	210 (75–450)	0.21
ICU stay, d	2 (0–12)	3 (0–55)	0.01
Hospital stay, d	12 (5–60)	14 (2–90)	0.10

Abbreviations: ASA, American Society of Anesthesiologists; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; GFR, glomerular filtration rate; ICU, intensive care unit; PAD, peripheral artery disease.
[a]Continuous data are presented as the means ± standard deviation or medians (range); categorical data are given as the counts (percentage).

Initially, a few small studies attempted to evaluate the influence of stent-graft complexity on the outcome of FEVAR.[6,7] Recently, 3 larger studies have reported results of FEVAR stratified according to landing zone and number of fenestrations.[2,3,8] Nevertheless, results have been conflicting, and the impact of the proximal landing zone on FEVAR outcome still remains unclear.[2,3,8,9] These discrepancies are enhanced by the lack of common reporting standards.

This study aims to evaluate early and midterm results of FEVAR in the treatment of abdominal aortic aneurysms (AAAs), comparing patients treated with fenestrated devices featuring renal-only fenestrations (RAs) and a scallop for the superior mesenteric artery (SMA) with patients requiring additional fenestrations for the SMA and the celiac artery (CA).

Methods

Between August 2006 and December 2014, 141 consecutive patients (mean age 72±7.6 years, range 50–89; 120 men) were electively treated with FEVAR for short-neck, juxtarenal, or suprarenal aortic aneurysms. Patients were assigned to 2 groups according to the configuration of the fenestrated stent-graft. Group A consisted of 45 patients treated with stent-grafts featuring renal-only fenestrations; group B included 96 patients with additional fenestrations for the SMA and/or the CA. The distributions of sex, age, and comorbidities in the groups are demonstrated in Table 1. Patients with type IV TAAAs requiring additional thoracic stent-graft components proximal to the fenestrated stent-graft were excluded. Patients with previous failed EVAR or open abdominal aortic surgery were not excluded. FEVAR as a technique was approved by the institution's ethics committee.

Aneurysm morphology was assessed by thin cut (≤1 mm) computed tomography angiography (CTA) with multiplanar reconstructions. The physical status of all patients was assessed preoperatively with the American Society of Anesthesiologists (ASA) score. The main indication for FEVAR included a proximal neck outside indications for use of infrarenal stent-grafts but otherwise suitable for EVAR in an AAA of at least 50 mm in diameter (or <50 mm with a perforating ulcer or in conjunction with iliac aneurysm >35 mm in diameter).

Stent-Grafts

Planning of fenestrated stent-grafts has been previously described in detail.[10,11] Briefly, stent-grafts were most commonly customized based on the Cook Zenith platform (William A. Cook Australia, Ltd, Brisbane, Australia). In 8 cases, where the distance between target vessel ostia was prohibitive for a fenestrated Cook stent-graft, a custom-made fenestrated Anaconda stent-graft (Vascutek Terumo, Inchinnan, Scotland) was applied. Fenestrations and scallops for the visceral vessels were fitted according to preoperative CTA measurements. The most common configuration consisted of a composite 3-part system with a proximal fenestrated tube, a distal bifurcated component, and a contralateral limb. In some cases of limited working length distally (eg, failed previous bifurcated surgical graft or EVAR), a fenestrated cuff only was used. Proximal and distal sealing zones ≥20 mm in length were always planned. In cases of common iliac artery aneurysm ≥35 mm in diameter, an iliac branched device (William A. Cook Australia) was applied.

Target vessels were routinely secured with a balloon-expandable Atrium Advanta V12 stent-graft (Atrium Maquet Getinge Group, Mijdrecht, the Netherlands). In cases of severe angulation, an additional self-expanding stent was applied [Zilver (William A. Cook Australia) or LifeStent (Bard PV, Tempe, AZ, USA)].

Procedure

The procedures were initially carried out in an operating room with a mobile C-arm (OEC 9900 Elite; General Electric Healthcare, Milwaukee, WI, USA); since January 2012, procedures were conducted in a hybrid operating room with fixed imaging (Allura Xper FD20; Philips Medical Systems, Best, the Netherlands). The operation was always done under general anesthesia, with surgical access via bilateral femoral cutdowns. The main operative technique has been described in detail previously.[4,11]

Heparinization was applied to maintain an activated clotting time ≥300 seconds. Intraoperative limb perfusion was monitored with a cerebral/somatic oxymetry system (INVOS; Medtronic, Minneapolis, MN, USA).

Cerebrospinal fluid (CSF) drainage for paraplegia prevention was applied in patients treated with stent-grafts featuring 4 fenestrations and in selected patients receiving 3 fenestrations who had prominent lumbar arteries in the intended proximal landing zone. The spinal catheter was inserted before intubation. Spinal fluid pressure was initially measured with a manometer equipped with a 3-way stop cock; beginning in 2011, pressure was monitored in a closed, pressure-controlled system (Liquo Gard; Möller Medical GmbH, Fulda, Germany) at a baseline of 12 cm H_2O. In such cases, the patient was postoperatively transferred to the intensive care unit (ICU), and systolic blood pressure was kept ≥80 mm Hg to increase perfusion of the spine through collateral circulation. In case of spinal cord ischemia (SCI), mean arterial pressure was adjusted to ≥90 mm Hg, and CSF pressure was set at ≤10 cm H_2O.

Technical success was defined as successful deployment of the planned stent-grafts with patent stented target vessels and absence of type I or III endoleak at the first postoperative CTA.

Postoperative Management

Patients were monitored with clinical and laboratory examination, CTA, and plain abdominal radiography in anteroposterior, lateral, and oblique projections prior to discharge. Further follow-up consisted of CTA at 1 month, 1 year, and annually thereafter, depending on each patient's characteristics. Patients were additionally monitored with ultrasonography at 6-month intervals by an experienced sonographer using a high-resolution ultrasound machine and a 5/1-MHz convex probe. Modalities applied included duplex, power Doppler with contrast enhancement, and contrast harmonic imaging with a low mechanical index (<0.2). SonoVue (Bracco, Milan, Italy) was administered to each patient intravenously as a 2.4-mL bolus injection. If the 1-year CTA, duplex ultrasound, and renal function were within normal limits, the need for further yearly CTAs was discussed in group with the intent to reduce the number of CTAs. If there was suspicion of endoleak or branch vessel malperfusion, digital subtraction angiography was carried out for further evaluation and possible reintervention.

Data Analysis

Variables are presented as mean ± standard deviation in case of normal distribution and median plus range in case of skewed distribution. Analyzed outcomes included technical success, operative time, contrast agent volume, early mortality and major morbidity, and late events with regard to target vessel stent patency, endoleak, reintervention, and death. Major morbidity was defined as the occurrence of clinically relevant pulmonary, cardiac, or gastrointestinal complications, postoperative deterioration of the glomerular filtration rate >30%, paraplegia/paraparesis, and local complications requiring surgical treatment.

The chi-square test was applied to compare categorical variables, while continuous data were compared using the Mann-Whitney-Wilcoxon test. Survival, target vessel stent patency, and reintervention during follow-up were subjected to Kaplan-Meier analysis and compared using the log-rank test; estimates are presented with the 95% confidence interval (CI). Statistical significance was set at $p<0.05$. Statistical analyses were performed using SPSS for Windows (version 20.0; IBM Corporation, Somers, NY, USA) and MedCalc (MedCalc Software, Ostend, Belgium).

Results

In total, 403 vessels were targeted with fenestrations (278 RAs, 96 SMAs, 29 CAs) and 110 vessels were targeted with scallops (3 RAs, 40 SMAs, 67 CAs). Preoperative characteristics examined were similar between the 2 groups. There was a higher tendency for previous aortic surgery in group B, but this did not reach statistical significance (p=0.07). In total, 36 patients had had previous aortic surgery. Thirteen patients were treated due to failed open abdominal aortic surgery and another 23 patients due to failed EVAR.

Operative Data and Technical Success

Mean operative time was 268±105 minutes (range 100–648), median fluoroscopy time was 45 minutes (range 10–160), and median contrast volume was 220 mL (range 75–450). There was no statistically significant difference between the groups in operative time (p=0.16) or contrast volume used (p=0.21), whereas fluoroscopy time was significantly longer in group B (p=0.01). Operative data are displayed in Table 1.

Technical success was achieved in 135 (95.7%) patients. In group A, 44 (97.7%) of the 45 patients has a successful procedure; 1 case was converted to open surgery as a result of failure to catheterize a very calcified and tortuous right RA. In the 96 group B patients, technical success was achieved in 91 (94.7%). One patient had heavily calcified iliac arteries bilaterally, and the stent-graft could not be introduced despite the use of an additional through-and-through wire via an axillary access. Multiple attempts to advance the stent-graft ultimately resulted in deformation and partial unsheathing of the graft in the iliac artery. The stent-graft was removed and the case converted. Another patient with a stenotic CA experienced an intraoperative dissection of the SMA, which occluded collateral circulation to the CA. The patient developed liver ischemia on the

first postoperative day and was treated with iliac hepatic bypass, but ultimately died. Catheterization of the right RA was not possible in 2 patients. In the first, who had a hypoplastic renal artery for the right kidney, the fenestration was positioned too high, and the vessel was left unstented. This led to early occlusion that did not affect the patient's renal function. In the second patient, an angulated right RA could not be catheterized from above or below, and an iliorenal bypass was carried out. In the last patient, catheterization of the CA was not possible, and the vessel was overstented with a proximal cuff. There was no statistically significant difference regarding technical success between the 2 groups (p=0.66).

Perioperative Mortality/Morbidity

Five (3.5%) patients died in the perioperative period. In group A, the 30-day operative mortality was 6.6% (3/45). One patient died due to mesenteric ischemia on the seventh postoperative day despite having a patent SMA and CA, most likely due to multiple visceral embolizations. One patient died on the third postoperative day after suffering multiple thromboses of both lower limbs and the intestinal arteries. Finally, the third patient had been treated with an aortouni-iliac stent-graft and a crossover femorofemoral bypass due to a heavily calcified left iliac artery. The bypass graft became infected, with erosive bleeding. It was replaced with a homograft, but the patient died due to cardiac complications at 30 days.

Operative mortality was 2.1% (2/96) in group B. The patient with SMA dissection described previously died due to liver ischemia on the second postoperative day. The second patient succumbed to multiple organ failure on the seventh postoperative day as a result of microembolization despite the fact that all targets vessels were patent. There was no statistically significant difference regarding perioperative mortality between the 2 groups (p=0.32).

Perioperative complications occurred in 16 (12.1%) patients, 3 (6.7%) were in the 45 group A patients. One patient suffered postoperative pneumonia but recovered completely. Two patients had surgical access problems that required surgical debridement. In the 14 (14.5%) of 96 group B patients, SCI occurred in 4 treated with stent-grafts featuring 4 fenestrations. The first patient was under CSF drainage, suffered temporary paresis of one lower limb, and recovered completely following adjustment of mean arterial pressure to ≥90 mmHg and drainage increase. The second patient developed paraparesis following probe clamping of the spinal catheter on the second postoperative day and recovered completely after reopening the spinal catheter. The spinal catheter was ultimately removed on the fifth postoperative day, following renewed probe clamping without SCI symptoms. The remaining 2 patients had preoperatively declined CSF drainage. Both patients suffered SCI with paresis of one lower limb, which resolved completely after placement of a spinal catheter.

Renal function deterioration occurred in 3 patients with known renal insufficiency. All patients had patent renal arteries. Two of these patients required temporary dialysis. In all cases, renal function recovered within 30% of the baseline value. Three patients developed ischemia of the sigmoid colon, which was treated with sigmoidectomy. One patient suffered a cerebral infarction with amaurosis and was treated successfully with lysis. One patient developed postoperative pancreatitis. Postoperative pneumonia occurred in 1 patient. Finally, the last patient developed a groin infection that required surgical debridement. There was no statistically significant difference between the 2 groups (p=0.27) in terms of morbidity.

Median hospital stay was 13 days (range 3–90) and median ICU stay was 2 days (range 0–55). Hospital stay did not significantly differ between the 2 groups (p=0.1), but group B patients had a significantly longer ICU stay (p=0.01).

Follow-up

Mean follow-up was 33±23 months and was slightly longer in group A (40±29 months) than in group B (30±19 months; p=0.07). Of the 34 deaths in follow-up, 3 were aneurysm-related (2 group A and 1 group B). In group A, the first patient died due to aneurysm rupture as a result of a type Ia endoleak. This patient had undergone banding of the proximal neck at 10 months postoperatively. The endoleak persisted but no further surgical measures were undertaken because the patient had in the meantime been diagnosed with renal cell carcinoma and lung metastasis. The second patient had a large aneurysm with persistent type II endoleak from the inferior mesenteric artery (IMA) and lumbar arteries. Laparoscopic clipping of the IMA was undertaken at 6 months. The endoleak persisted, and the aneurysm grew from 68 to 75 mm. A laparotomy with aortotomy and lumbar artery suture was carried out at 44 months. The patient died as a result of cardiac complications following the procedure.

In group B, 1 patient developed an aortoduodenal fistula at 3 months. This patient had been treated for rapid expansion of a juxtarenal aneurysm after failed standard EVAR with signs of infection. The fenestrated stent-graft was partly replaced with an antimicrobial silver-coated graft; the patient had a prolonged hospital stay and ultimately died due to multiple organ failure at 5 months postoperatively. Overall estimated survival was 85.1% (95% CI 79.1% to 91.1%) at 1 year and 75.8% (95% CI 68.2% to 83.5%) at 3 years. For group A, overall survival estimates at 1 and 3 years were 88.4% (95% CI 78.9% to 97.9%) and 75.6% (95% CI 61.6% to 89.6%); for group B, the estimates were 83.6% (95% CI 76.0% to 91.2%) and 76.3% (95% CI 67.5%

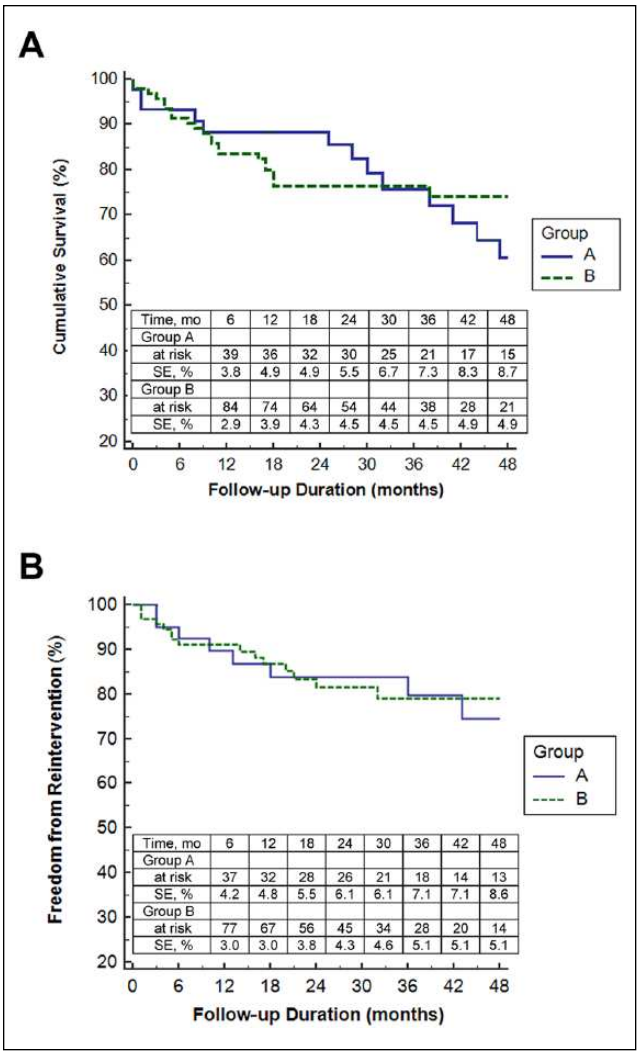

Figure 1. Kaplan-Meier graphs of (A) cumulative overall patient survival and (B) freedom from reintervention in groups A and B.

Table 2. Cases Requiring Reintervention.

Group	Reason	Lapsed Time, mo	Procedure
A	RRA/LRA occlusions	1	Failed
	RRA/LRA stenosis	13	BE stent-graft
	RRA stenosis	36	BE stent-graft
	SMA/CA stenoses	72	BE stent-graft
	LRA pseudoaneurysm	43	Failed
	Type II EL (lumbar)	3	CE + Onyx injection
	Type II EL (IMA)	6; 44	Laparoscopic clipping; laparotomy
	Type II EL (lumbar)	60	CE + Onyx injection
	Type Ia EL	10	Proximal banding
	Type Ia EL	18	4× FEVAR
	Type III EL	3	Limb relining
B	SMA stenosis	6	BE stent-graft
	LRA/RRA stenoses	14	DEB angioplasty
	LRA stenosis	16	DEB angioplasty
	SMA stenosis	17	BE stent-graft
	CA stenosis	20	BE stent-graft
	Type II EL (IMA) + SMA stenosis	4; 8	Laparoscopic clipping; BE stent-graft
	Type Ib EL (iliac) + RRA/SMA stenoses	5; 16	IBD right IIA; BE stent-graft
	Type II EL (IMA + lumbar)	1; 16	Laparoscopic clipping; laparotomy
	Type II EL (IMA)	5	Laparoscopic clipping
	Type II EL (IMA)	21	CE
	Type II EL (IMA + lumbar)	24; 30	Laparoscopic clipping; laparotomy
	Type Ib EL (CA)	32	BE stent-graft
	Type III EL (NA)	1	Bridging BE stent-graft
	Access problem (SMA)	1	Transbrachial BE stent-graft
	Aortoduodenal fistula	3	Conversion

Abbreviations: BE, balloon-expandable; CA, celiac artery; CE, coil embolization; DEB, drug-eluting balloon; EL, endoleak; FEVAR, fenestrated endovascular aneurysm repair; IBD, iliac branched device; IMA, inferior mesenteric artery; LRA, left renal artery; RRA, right renal artery; SMA, superior mesenteric artery.

to 85.2%), respectively (p=0.96). Cumulative survival is demonstrated in Figure 1A.

Eight target vessels occluded in follow-up, 5 left RA, 1 right RA, and both renal arteries in 1 patient. In 5 patients, the reason for the occlusion was adverse anatomy (3 narrow RAs with early bifurcation and 1 small accessory RA). In 1 patient, the left RA developed a pseudoaneurysm at the end of the Advanta V12 stent-graft. An unsuccessful attempt was undertaken to extend the stent-graft deeper into the RA, but the vessel ultimately occluded. In 1 patient, the left RA occluded following gastrointestinal bleeding with hypotension. Finally, in the last patient the RA occluded in the context of B-cell acute lymphoblastic leukemia. Renal function did not deteriorate in 4 of 7 patients with RA occlusion. In 2 patients, renal function deterioration >30% was noted, without the need for dialysis. The patient with bilateral RA occlusion presented in the emergency department after 1 week of ongoing pain; a recanalization attempt was unsuccessful, and the patient became dialysis dependent. Target vessel patency estimates at 1 and 3 years were 97.2% (95% CI 94% to 100%) for group A and 98.9% (95% CI 97.8% to 100%) for group B, respectively (p=0.11).

Unplanned reinterventions were required in 26 (18.4%) patients during follow-up. The reasons for reintervention and reintervention time are listed in Table 2. Eleven (24.4%) of the 45 group A patients required reintervention. In 3, the reason was stenosis of a target vessel. In another 3, reintervention was required due to persistent type II endoleak with aneurysm progression. Of the remaining 5 patients, 2 were treated for a type Ia endoleak, 1 for bilateral RA occlusion, 1 for the previously mentioned RA pseudoaneurysm, and 1 for a type III endoleak from the left iliac limb.

In group B, 15 (15.6%) of the 96 patients underwent a reintervention. Five patients were treated for stenosis of a target vessel and 4 for type II endoleak. In 2 patients, an

initial reintervention was required due to a type II and a type Ib endoleak, respectively, that was later followed by a second reintervention due to target vessel stenosis. Of the remaining 4 patients, 1 was treated for a type Ib endoleak from the CA and another for dislocation of the RA stent-graft and type III endoleak. In a patient in whom the CA could not be catheterized from the groin and the respective fenestration was left unstented, the fenestration was stented 2 weeks postoperatively via a brachial access. The final reintervention was in the patient who developed aortoduodenal fistula and had to be converted. Overall freedom from reintervention was 90.6% (95% CI 85.6% to 95.6%) at 1 year and 79.2% (95% CI 71% to 87.5%) at 3 years. The estimates were 89.8% (95% CI 80.2% to 99.4%) and 79.7% (95% CI 66% to 93.4%), respectively, in group A and 91.0% (95% CI 85% to 97%) and 79.1% (95% CI 69.2% to 89%), respectively (p=0.76), in group B. Estimated freedom from reintervention is demonstrated in Figure 1B.

Endoleaks were detected during follow-up in 25 (17.7%) patients. In group A, 6 (13.3%) patients had endoleaks (3 type II, 2 type Ia endoleak, and 1 type III) and were all treated. In group B, 19 (19.7%) patients had endoleaks (16 type II, 2 type Ib, and 1 type III). Reintervention was required in 8 of these patients. The type II endoleaks in 11 patients were not associated with aneurysm progression and were treated conservatively. There was no statistically significant difference in endoleaks between the 2 groups (p=0.47).

Discussion

FEVAR is a well-established technique for the treatment of complex AAs, with numerous reports showing good early results and midterm durability.[2,12,13] As interventionists have become more confident with the use of complex endovascular techniques, increasingly challenging pathologies are now being treated with FEVAR. It is therefore important to stratify results according to aortic anatomy and technical complexities.

Several reports have compared FEVAR results with regard to stent-graft complexity.[2,3,6–9] Results have been inconsistent, partly due to the differences in reporting standards. Some authors include type IV TAAAs in the statistical analysis as well as patients treated with branched stent-grafts.[2,8] Furthermore, there is a lack of consensus regarding how to classify JAAs and SAAs and the subsequent extent of repair. Result stratification has been carried out according to several different standards, with other authors comparing renal-only fenestrations to more complex designs, while others apply the aneurysm zone classification or the Society for Vascular Surgery/American Association for Vascular Surgery anatomical severity score.[7–9]

It is our belief that stratification of FEVAR results in the abdominal aorta should be limited to abdominal aortic pathology. The current series compared solely patients with JAAs and SAAs excluding patients with TAAAs. The use of branches is generally associated with thoracoabdominal pathology, so patients treated with branched stent-grafts, which require a significantly more complex procedure using an additional axillary access, were also excluded from the study.

The classification of patients in this study (renal only fenestrations and a SMA scallop vs additional SMA or CA fenestrations) reflects procedural complexity in relation to the number and position of the vessels that require catheterization. As more fenestrations are added, additional catheterizations and wire manipulations are required, which increases the risk of vessel dissection. High-quality lateral imaging for the SMA and CA is required, especially in obese patients, which in return makes such procedures in nonhybrid operating rooms problematic. More lumbar arteries are overstented, which increases the risk of SCI and, in our view, necessitates the use of CSF drainage. There was no differentiation between zone 7 and zone 8 aneurysms since our procedures occasionally feature an additional fenestration for the CA but leave that fenestration unstented as opposed to using a proximal CA scallop.

Baseline demographics were balanced between the 2 groups, and technical success did not differ significantly. Overall 30-day mortality in this series was similar to a recent review from Di et al,[12] in which a 2.52% pooled estimate for 30-day mortality was reported. While 30-day mortality did not differ significantly between the 2 groups, group B patients had a nonsignificant higher rate of perioperative complications. It has to be noted that 4 group B patients developed temporary SCI, which is in accord with a recent report from Mastracci et al,[2] associating the length of graft coverage to SCI. In all 4 cases, symptoms regressed following CSF drainage, highlighting its importance for SCI prevention and treatment. Insertion of the spinal catheter was also likely the reason patients in group B had a longer mean ICU stay.

Estimated survival and target vessel patency rates were high in both groups, confirming the midterm efficacy of FEVAR reported in other studies.[2–4] Notably, 2 group A patients had proximal type I endoleaks as opposed to zero in group B. One of these endoleaks resulted in an aneurysm-related death, whereas in the second case additional treatment with a stent-graft featuring 4 fenestrations was necessary. There is an ongoing debate regarding the fate of type II endoleaks in EVAR and FEVAR. Although type II endoleaks are usually treated conservatively, a persisting type II endoleak with ongoing aneurysm progression is in our opinion an indication for treatment. First, an attempt is made to selectively catheterize the respective vessel for angiography and coil embolization of the IMA or lumbar arteries. In case of catheterization failure with endoleak

persistence and aneurysm growth, laparoscopic clipping of the IMA becomes necessary.

The impact of landing zone level on FEVAR outcome is an essential question as complex endovascular techniques advance and off-the-shelf fenestrated stent-grafts are released. The question this article attempts to address is: Should fenestrations be limited to the minimum required to achieve proximal seal or is it wiser to have a low threshold when deciding to increase the coverage of the visceral aorta to ensure the durability of the repair? This study indicates that there appears to be no increased risk to including suprarenal fenestrations when treating abdominal aortic pathology, with the benefit of an improved perirenal aortic sealing. Although additional fenestrations increase procedural complexity, endovascular specialists should not hesitate to extend the proximal landing zone to or above the CA when necessary.

Limitations

The number of patients is too low to support robust statistical conclusions. Furthermore, these procedures took place in a high-volume center with experience in complex endovascular procedures, so the results may not be generalizable to less experienced operators/centers.

Conclusion

The use of FEVAR for JAAs and SAAs is associated with low 30-day mortality and morbidity and high midterm efficacy. So far, perioperative and midterm results are not affected by the use of more complex fenestrated designs featuring fenestrations for the SMA and the CA.

Declaration of Conflicting Interests

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